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WORKING GROUP REPORTS

During the afternoon of the second day of the Workshop, participants joined one of four working groups to discuss technical aspects of the precautionary approach. This section contains their reports. The four working groups were more or less defined by level of information complexity, as explained below. The first three groups are relevant to single-species approaches to setting target and limit harvest levels when that can be accomplished effectively. The last group is relevant to multi-species approaches to setting harvest levels, even though the stock assessments may be carried out on a single-species basis for each stock in the complex.

1. <u>Information-rich cases</u>: Reliable estimates of MSY-related quantities and current stock size are available. Harvest control rules typically involve parameters such as F_{MSY}, B_{MSY}, etc. Stock assessments may be sophisticated, and provide a reasonably complete accounting of uncertainty.

2. <u>Intermediate cases</u>: Reliable estimates of MSY-related quantities are either unavailable or of limited use due to peculiar life history or high recruitment variability, but reliable estimates of current stock size and all critical life history (e.g., growth) and fishery (e.g., selectivity) parameters are available. Harvest control rules typically involve parameters such as $F_{35\%}$, $B_{35\%}$, etc., or other proxies for MSY-related benchmarks. Stock assessments may range from simple to sophisticated and uncertainty can be reasonably characterized and quantified.

3. <u>Information-poor cases</u>: Reliable estimates of MSY-related quantities are unavailable, as are reliable estimates of either current stock size or certain critical life history or fishery parameters. Harvest control rules typically involve parameters such as M, historical average catch, etc. Stock assessments are minimal, and measurements of uncertainty may be qualitative rather than quantitative.

4. <u>Mixed-information cases in multi-species settings</u>: Target and limit harvest levels for each species in a fishery may need to be established jointly with those for the other species in the fishery, as the stocks are harvested together and cannot be targeted or effectively managed independently. Within constraints specified by the proposed national standard guidelines, it may be necessary to overfish one or more species in order to achieve OY for the complex. Reliability of MSY-related quantities, current stock size, and other parameters, may range from high to low for the various stocks in the complex. Stock assessments vary from minimal to sophisticated, and uncertainty characterization ranges from qualitative to reasonably complete.

Central questions

According to the guidelines for National Standard 1, a precautionary approach should contain three main features: "*<u>First</u>, target reference points, such as OY, should be set safely below limit reference points, such as the catch level associated with the maximum fishing mortality threshold. <u>Second</u>, a stock that is below its MSY level should be harvested at a lower rate or level of fishing mortality than if it were above its MSY level. <u>Third</u>, the criteria used to set target catch levels should be explicitly risk averse, so that greater uncertainty regarding a stock's status or productive capacity corresponds to greater caution in setting target catch levels*" (Federal Register, Aug. 1997, Volume 62, Number 149).

A central question is the development of frameworks for control laws, e.g. a relationship between management recommendations and stock assessment results. These control laws can be used to define a limit that cannot be exceeded, and/or a management target that is safely below the limit. The working groups should aim to provide practical advice on these features for their level of information complexity. A preliminary set of questions for each group to consider is:

1. How to define control laws that can be implemented and monitored with available information and that are consistent with the proposed National Standard Guidelines?

2. How to quantify or categorize uncertainty (in biological relationships and assessment results) so that it can be incorporated into control laws?

3. How to describe tiers of uncertainty so that lack of information truly leads to greater caution?

4. How to calculate and communicate assessment results so that they facilitate and encourage risk averse management actions, but leave opportunity for the management process to incorporate other considerations?

5. How to include other approaches, such as the use of marine protected areas or other gear/size/time/area restrictions?

Report of the "Data-Rich" Working Group

Chair: G. G. Thompson

General Procedure

In general, the following procedure is suggested for specifying limit and target control rules:

1) Consider a candidate limit control rule.

a) How does it qualify as an MSY control rule (i.e., in what sense would long-term average yield be maximized by the control rule's sustained application)?

2) Consider a candidate target control rule.

a) How does it satisfy the following three requirements of a precautionary approach?

i) target <= limit
ii) F(low stock size)<F(high stock size)
iii) F(high uncertainty)<F(low uncertainty)

More Specific Procedure

For an n-parameter control rule, it may be easiest to fix n-1 parameters *a priori* through a simple rule or formula, and treat only the remaining control parameter as free.

1) For the limit, the Group suggests setting the free control parameter at the value that maximizes expected stationary yield, or something analogous.

2) For the target, one of the following options is suggested:

a) set the free control parameter at the value that maximizes expected log stationary yield, or something analogous.

b) set the free control parameter at the value where the probability of the true fishing mortality rate exceeding the limit control rule is α.

Examples of Control Rules

The following are some control rules that the Group felt at least somewhat positive about:

One-Parameter Control Rules

1) $f(x)=F$
Comments: This control rule does not satisfy the second requirement of a precautionary approach. Probably results in a minimum stock size threshold close to x_{MSY}. A good proxy for the target control rule might be the harmonic mean of the pdf of deterministic F_{MSY}.

Two-Parameter Control Rules

2) $f(x)=F+bx$
3) $f(x)=F+b\ln(x)$

Three-Parameter Control Rules

4) $f(x)=a+bx$ for all $x<(F-a)/b$
$f(x)=F$ for all $x>(F-a)/b$

A special case:

4a) $(F-a)/b=x_{MSY}$, i.e.,
4ai) $f(x)=a+bx$ for all $x<x_{MSY}$
$f(x)=a+bx_{MSY}$ for all $x>x_{MSY}$, or
4aii) $f(x)=a+(F-a)(x/x_{MSY})$ for all $x<x_{MSY}$
$f(x)=F$ for all $x>x_{MSY}$, or
4aiii) $f(x)=F+b(x-x_{MSY})$ for all $x<x_{MSY}$
$f(x)=F$ for all $x>x_{MSY}$

Comments: To minimize the potential for mischief, the Group recommends that F be treated as the free parameter. In order to qualify as an MSY control rule, F will probably have to be greater than the F_{MSY} level calculated under control rule 1. The minimum stock size threshold may still be close to x_{MSY}.

5) $f(x)=a+bx$ for all $x<(F-a)/b$
$f(x)=F/x$ for all $x>(F-a)/b$

A special case:

5a) $$\frac{-a+\sqrt{a^2+4bF}}{2b}=x_{MSY},$$

with three ways of eliminating a parameter as in 4a.

Comments: The same comments as in 4a apply. This control rule satisfies the second requirement of a precautionary approach only for stock sizes below x_{MSY}.

Suggestions for Setting α

The "alpha" approach defines the target control rule by specifying a probability that the true fishing mortality rate, though intended to equal the *target*, may actually exceed the *limit*. Values for α suggested by members of the Group included 0.05, 0.10, and 0.20. It was also suggested that α be set on a case-by-case basis, because methods of expressing variance and uncertainty are not consistent across stock assessments and because fixed values of α may be too conditional on model specification and error distribution assumptions. Most Group members were generally pessimistic regarding the "alpha" approach, though it should not be ruled out as an option.

Suggestions for Rebuilding Rates

The Group had little advice to provide in terms of choosing an appropriate rate of rebuilding. It was suggested that phrasing the discussion in terms of the stock size below which the fishery would close might help Councils to view the question in practical terms. Some members of the Group believe that it would be valuable to have at least default measures for rebuilding defined *a priori*. Doing this might help to prevent excessive delay in implementing rebuilding plans when the stock is at a critically low level.

Report of the "Data-Moderate" Working Group

Chair: Richard Methot

Introduction

This Group was charged with developing recommendations for applying the precautionary approach to situations in which a quantitative stock assessment can be conducted, but there is insufficient information to develop a reliable estimate of MSY. The general features of harvest control rules developed for data-rich situations should apply to data-moderate situations and are not considered further here. However, by definition, the data-moderate harvest control rule will need to use a proxy for F_{MSY}. In addition, the data moderate situation is likely to have higher variance in estimates of stock abundance and harvest rates.

A primary outcome of the working group's deliberations was dissemination of the general principles of the harvest control rules, precautionary approach, and rebuilding plans. This aspect of the small-group discussion is not reported here, but was a major benefit from this opportunity.

Proxies for F_{MSY}

A primary consideration for data-moderate situations is identification of a suitable proxy for Fmsy. It is now common to express these proxy harvest rates in terms of their expected impact on spawning biomass (itself a proxy for reproductive output) per recruit. Harvest rates in the range of $F_{35\%}$ to $F_{45\%}$ have been proffered as reasonable proxies for MSY, and $F_{20\%}$ was used as an overfishing threshold for many stocks during the mid-1990s (Rosenberg et al). The actual level of the proxy harvest rate will be based upon information gleaned from comparable, data-rich stocks; life history characteristics of the stock in question; and selectivity characteristics of its fisheries. The working group recommends continued efforts to conduct a meta-analysis of stock productivity estimates in order to guide selection of suitable proxies for individual stocks.

The working group recommends calculating harvest rates under current selectivity patterns, including the current mixture of fisheries with different selectivity patterns. This avoids confusing allocation issues with optimum yield issues. However, these allocation and selectivity issues may need to be re-considered when a rebuilding plan is developed.

One impediment to estimating MSY is lack of contrast in spawning biomass levels, even though data quality may be sufficient to obtain good estimates of current abundance and harvest rates. Successful future management under a MSY proxy may further delay observing the stock at contrasting biomass levels. If the proxy is too aggressive (i.e. greater than the true Fmsy), then the stock will decline and information about the true Fmsy will be obtained. However, if the proxy is too conservative, then we will have little opportunity to learn whether or not the stock is capable of producing a greater yield. In this circumstance, only extreme natural fluctuations in recruitment will allow collection of information about stock productivity at different stock levels. If it is suspected that the proxy is much too conservative, then a carefully controlled adaptive management regime could be used to probe contrasting biomass levels in order to improve the estimate of long-term MSY.

This MSY-based distinction between data-moderate and data-rich assessments can turn into a smooth transition when assessments are conducted with Bayesian methods to introduce a prior distribution on the curvature of the stock-recruitment function. In this case, the same sort of information that currently is used to establish a proxy will be used to specify a prior distribution on the potential stock productivity. When there is little actual data from the subject stock, this prior will dominate the result. As stock-specific data accumulate, the posterior estimate of the stock's productivity will be drawn towards the information from that stock.

Variance Components

In the evaluation of the potential performance of a F_{MSY} proxy, it is important that the major components of variance are identified so that appropriate precautionary adjustments can be recommended. The evaluation should be based upon simulation studies that include relevant types and levels of assessment uncertainty, variability in recruitment on a range of relevant time scales, and potential variance in the management application of the recommended harvest control rule.

The assessment uncertainty includes three components of variance. First is the suitability of the proxy for F_{MSY}. Clearly we cannot do this perfectly, otherwise we would know MSY for each stock already. Any future meta-analysis of stock productivity should attempt to estimate this component of variance. Second is the estimate of the harvest rate that would correspond to the selected proxy. This depends on technical estimates of growth, mortality, maturation, and fishery selectivity. While this component of variance may be relatively low for many stocks, it should not be ignored in the evaluation of the proxy's performance. Finally, accurate implementation of the proxy depends upon accurate estimates of current stock abundance and harvest rates.

The level of precaution should decrease monotonically as the level of true variance decreases. Unfortunately, our "best" estimates in data-poor situations rarely have a relevant variance estimate and rarely result in a large precautionary adjustment. As we emerge from data-poor situations and begin to conduct quantitative assessments with variance estimates, we often find that these first estimates of variance are very large. It is important that the way in which these large estimates of variance enter into precautionary harvest control rules not be an impediment to acceptance of these first variance estimates. Thus, when data quality or model methods are insufficient to develop good estimates of assessment variance, it may be necessary to develop a proxy for assessment variance itself.

Report of the "Data-Poor" Working Group

Chair: Alec MacCall
Rapporteurs: Loh-Lee Low and Pamela Mace

Introduction

This Group was charged with developing recommendations for applying the precautionary approach to data-poor fishery cases. "Data-poor" refers to cases where standard stock assessment tools (ADAPT, Stock Synthesis, CAGEAN, etc.) cannot be applied because of insufficient data. For the purpose of this group's discussions, it is assumed that formal MSY estimates or proxy policies such as those based on spawning potential per recruit (SPR) cannot readily be developed. Data series may be incomplete, censored (in the statistical sense, possibly due to a prior history of restrictive management), or simply lack sufficient contrast to define critical relationships, such as between effort and catch per unit effort.

We are obligated to use available information, however poor or incomplete, to implement a management policy consistent with the revised MSFCMA and National Guidelines. The challenge is to gain some indication of current abundance (B) and fishing intensity (F), and to relate these estimates to corresponding reference points, B_{MSY} and F_{MSY}. This can be very difficult to do in a data-poor case, and the resulting imprecision necessarily merits a precautionary approach.

Simple, practical methods for assessing data-poor stocks or fisheries were developed extensively by FAO and others during the 1960s and 1970s. Use of these methods has declined in recent years, perhaps associated with the rise of computationally intensive methods often requiring richer data sets. However, the simple methods were designed especially for data-poor cases of the sort being considered here, and a review of those methods would be a worthwhile first step toward stock assessment. Some of those approaches may require modification to meet the present requirement for precaution.

The category of "data-poor" or "information-poor" situations encompasses a wide variety of possibilities, and defies generalization. Some examples are:

- Nearly total lack of data
- Catch history consist of poorly monitored bycatch
- Historical catches or rates may have been constrained (e.g., squid)
- Catch history is known, but little biology (e.g., scallops)
- No fishery, but history of surveys or indexes
- Fishery occurs only in a small portion of range (e.g. blue shark in Hawaii)
- Under-developed fishery, only knowledge is from an experimental fishery
- Peculiar life history traits (e.g., hermaphroditic groupers)

The Group preferred to consider individual examples spanning a representative variety of actual fishery cases. These cases are taken progressively in approximate order of information richness. The final example treats the special case of a newly-developing fishery. All of these cases tend to address the problem of stock assessment. Stock assessment serves two purposes in the present context: It reduces (or at least quantifies) uncertainty, and it defines the options available for precautionary management.

Example 1 -- Very poor information

There are some fishery resources for which we have almost no information whatsoever. The early development of Australia and New Zealand's orange roughy fisheries are example cases. Best available information may consist of little more than expert opinion. Formalization of that information or advice is beneficial, and techniques such as the Delphi Method provide a means of comparing and cross-checking different individuals' expert opinions. Qualitative stock assessment may be appropriate, e.g., abundant vs. depleted, or lightly exploited vs. heavily exploited.

With only slightly more information it may be possible to use analogies drawn from similar species or resources that have better-known properties. A large number of the west coast's rockfish (*Sebastes* spp.) could fall in this category. As information becomes more quantitative, analogies may be formalized into meta-analysis or Bayesian treatments, and precaution can be quantified by appropriate loss functions.

Example 2 -- Some catch history

Quite often there is a history of estimated catches, but little else. The catches may be from a directed fishery or perhaps from estimated by-catch in other fisheries. All of the approaches suggested in the previous example apply equally in this case. Because exploitation is already underway, development of more information is urgent Catch alone is not an adequate basis for managing a fishery and should be supplemented by other information as soon as possible. Unless an arbitrary level of catch has been maintained for an exceptionally long period of time (several times the maximum fish lifespan), there is little basis for assuming that an existing catch level is actually sustainable. The "reversal of proof" aspect of the precautionary approach requires that the catch level be proven to be sustainable rather than assuming it is sustainable and requiring proof to the contrary. An interim precautionary approach might be to restrict allowable catches to 75% of their historical average, or some other percentage value based on qualitative perceptions of resource condition, e.g., based on fishermen's perceptions of trends in catch rates.. Mace (personal communication) has conducted simulations suggesting that percentages in the range 60%-90% are often appropriate.

In many respects, this is the most challenging scenario for implementing a precautionary approach. Because there is an existing fishing tradition, there are likely to be strong advocates for continuing or even expanding harvest despite a general lack of information. Although the National Guidelines indicate that this condition of high uncertainty should result in strong precaution, it is not clear what is gained by a precautionary reduction in what may already be an arbitrary level of harvest. The key to solving this problem is development of a stock assessment (perhaps qualitative) based on expert judgement if necessary, and using that assessment as the basis for advice on precautionary measures.

Example 3 -- Some catch history with minimum biological knowledge

This is perhaps the most common "data-poor" case. In the 1960's and 1970's the FAO and others developed a variety of stock assessment tools for treating this information level, and some of those approaches merit reconsideration. A tentative natural mortality rate can be inferred from simple growth or age information, using analogies to better-known species. Changes in age or size compositions over time may reveal trends in recruitment or exploitation effects. Virtual Population Analysis (VPA) of synthetic cohorts, or length-based VPA may provide rough estimates of fishing mortality rate and population size. Age determinations should be validated if possible.

A popular management rule-of-thumb has been to set the fishing mortality rate (F) approximately equal to the assumed natural mortality rate (M), i.e., F=M. Gulland's potential yield estimate of MSY = ½MB_o, where B_o is the estimated unfished abundance, is roughly equivalent to this policy if B_{MSY} is assumed to be ½ B_o as in a Schaefer or logistic model. A precautionary approach would be to reduce the fishing intensity from this level to perhaps F = 75%M. If there are other indications of potential vulnerability to overfishing (e.g., fish become available to fishing before they mature, or if recruitment events are rare and widely separated in time), the precautionary reduction in fishing intensity should be greater.

Example 4 -- Catch history and some survey information

This case borders on "data-intermediate," depending on the extent and information content of the survey. Assuming that the species under consideration was not a target of the survey(s), conversion of the survey results to an absolute abundance estimate may be difficult. If the surveys provide a series of tentative abundance indexes, production modeling may be possible. A precautionary approach could be based on the precision (coefficient of variation) of the survey estimate or index, including the calibration procedure. Simulation modeling may provide useful guidance.

Example 5 -- Data are available for only a portion of stock range

Information on oceanic and/or transboundary stocks may be limited to a small portion of the presumed range (e.g., many highly migratory species such as tunas and sharks). It may be possible to draw limited inferences of stock characteristics by analogy or by comparison with known oceanographic properties. While it is nearly always desirable to engage agencies responsible for other parts of the range, in many cased actual management must be unilateral. Identification and clarification of objectives will provide useful guidance to management. With respect to these objectives, simulation of alternative stock structures and dynamics may help assess risks associated with unilateral management of a portion of the range, and help identify appropriate precautionary adjustments. If the managed portion of the range is small, risk may be low and there may be relatively little need for explicit precaution.

Example 6 -- Short CPUE series lacking contrast

Although it may not be possible to assess the stock quantitatively (e.g., by production modeling), a precautionary approach would be to establish a threshold CPUE below the current level so that a future drop in CPUE would automatically trigger a precautionary management response.

Example 7 -- Peculiar life history

Unusual or peculiar life histories may require added precaution. Often the nature of the risk can be inferred logically, but is difficult to quantify. The demographic structure of protogynous hermaphrodites such as groupers can easily be disrupted by exploitation, especially if the large males are preferred fishing targets. In California, a fishery for sheep crab (family Majidae, the spider crabs) claws poses another unusual life history problem: These crabs undergo a terminal molt, and adults cannot regenerate a lost claw, posing a risk of decreased survival and/or reproduction of clawless crabs returned to the water.

Example 8 -- New fishery

Planned fishery development should incorporate an objective of generating the information necessary for managing the resource. This includes not only fundamental data collection, but also a controlled pace of development that is sufficiently slow that optimal fishing rates and abundance levels can be estimated before those levels have already been exceeded, i.e., to avoid overshooting MSY. “Fishing down” of the standing stock provides a large windfall yield that is not sustainable, and can create false expectations of continuing high harvest levels, especially for long-lived species. A simple rule-of-thumb, based on the potential yield estimate described above in Example 3, is that the ratio of windfall to maximum sustainable yield is equal to 1/M, i.e., $MSY = ½MB_o$, and $Windfall = ½B_o$, so $Windfall/MSY = 1/M$. For a species with $M=0.1$, fishing down of the virgin stock will yield a one-time harvest tenfold greater than the annual sustainable yield. Even if this windfall harvest were spread over ten years, those ten years would see average harvest levels substantially greater than the sustainable levels that must eventually support the fishery.

Traditional fishery management provisions such as size limits and closed areas and/or seasons may be useful auxiliary tools to assure that sufficient precaution is taken in development of a new fishery.

Recommendation

Stock assessment is the first element of precaution, and an attempt at assessment must be made whatever the level of available information. This includes qualitative stock assessments based on little more than expert opinion, if that is all that can be done. A large fraction of the nation’s fish resources have never been assessed. A nationwide effort should be made to assess all stocks under federal management.

Report of the “Multi-species” Working Group

Chair: Wendy L. Gabriel

Multispecies Aspects addressed in the Magnuson-Stevens Fishery Conservation and Management Act

The Act’s requirements to prevent overfishing are not restricted to commercial species. Recreational and subsistence fisheries are also affected and must be managed to achieve optimal yield. The requirement to minimize bycatch (fish harvested in a fishery but not sold or kept for personal use) extends to all fisheries.

The MSFCMA includes the importance of a variety of multispecies effects within an ecosystem context. Within the Act, the definition of “optimum”, with respect to yield from a fishery, is the amount of fish which provides the greatest overall benefit to the Nation, taking into account the protection of marine ecosystems.

Precautionary advice must thus consider the impacts of fisheries on non-target species including discard species and forage species; as well as short-term and long-term ecosystems effects. Characteristics such as species composition and diversity (and its variance) consequently become important in the ecosystem context.

Prevention of Overfishing in the Multispecies Context

<u>National Standard Guidelines</u>

The draft National Standard Guidelines allow exceptions to the requirement to prevent overfishing in the case of a mixed-stock complex. If one species in the complex is harvested at OY, overfishing of other components in the complex may occur if 1.) long-term net benefits to the Nation are obtained and 2.) similar long-term net benefits cannot be obtained by modification of fleet behavior or gear characteristics or other operational characteristics to prevent overfishing and 3.) the resulting fishing mortality rate will not cause any species or ecologically significant unit to require protection under the ESA, or any stock or stock complex to fall below its minimum stock size threshold[1]. Thus, the fishing mortality rate for a stock in a mixed-stock fishery may exceed the limit rate if this will not cause the stock to fall below a.) ½ B_{MSY}, or b.) the minimum size at which rebuilding to the MSY level would be expected to occur within 10 years (if the stock were exploited at the limit fishing mortality rate), whichever biomass level is larger.

Precautionary Implications

When co-occurring species are harvested simultaneously by the same gear type, a single level of fishing effort may give rise to a wide variety of different fishing mortality rates on individual stocks. This is because catchability (vulnerability) of each co-occurring species by the gear type is likely to be different.

When more than one stock in the complex becomes fished at rates above their limits, especially when rates are substantially above limits, the risk of falling below biomass limits may increase for several species; and in a precautionary context, control rules which reduce the risk to the complex should be implemented, to prevent the need for rebuilding multiple overfished stocks.

The discussion group noted that aggregate TACs were not precautionary. The National Standard Guidelines provide for specification of a fishery-wide OY for a mixed-stock fishery, where management measures for separate harvest levels for individual stocks may be specified, but are not required. Although the guidelines recommend that the sum of individual target levels be less than fishery-wide OY, if individual OY levels are not specified and the entire OY could be removed from one or few unproductive stock components, overfishing of those components could occur: under those circumstances, a precautionary approach should be used minimize the risk of successive removals of the least productive components in the mixed-stock fishery. Management to prevent overfishing of the least productive components will afford significant protection to marine ecosystems in terms of maintaining species diversity, and associated species interactions including trophic structure.

Recommended Precautionary Control Rule for Multispecies Fisheries

Precautionary management of a multispecies complex must be based on the harvest control rules which applies to the least productive, weakest or least resilient stocks in the complex.

If a single species in the complex is being maintained at its optimum yield, then individual species biomasses of other species in the complex must each be greater than the established minimum stock size threshold (MSST) for each individual species. It must be possible to rebuild each individual stock to B_{MSY} in 10 years or less (at F = F to rebuild). B_{MSY} in this context refers to B_{MSY} for the individual stock, not an aggregate for the complex.

Data-Poor Situations

In some multispecies fisheries, there may be a large amount of information about population dynamics and status of principal (e.g., target commercial or recreational) species, but relatively little may be known about some or most of the species within the complex. Most fisheries are in fact multispecies fisheries when the impacts on non-target organisms are taken into account. The most precautionary harvest control rules would be expected for species with the least information. Consequently, harvest control rules for data-poor species can drive the management of the entire complex, when management is precautionary.

Because precautionary management applies to non-target as well as target species, catches and harvest control rules for species which are always discarded could result in management of the complex based on the status of bycatch species or non-target species. However, National Standard 9 requires that *"Conservation and management measures shall, to the extent practicable, (A) minimize bycatch, and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch."* National Standard 9 always applies, and may mitigate the impacts on non-target organisms.

The discussion group recommended that observer programs be established to measure discards. In addition, research is needed to determine the impacts of cryptic mortality on fish stocks. Indirect impacts may be significant, and there may be non-fishery effects which are not accounted for, including predator-prey interac-

[1]In the final rule National Standard Guidelines, the third criterion is modified so that the only condition is that the resulting fishing mortality rate will not cause any species or ecologically significant unit to require protection under the ESA, with no other restrictions on exceeding limit rates.

tions, competition, evolutionary interactions, and effects of changing habitats.

Conclusions

The first line of defense in precautionary management of multispecies complexes is to change selectivity for species near their individual minimum stock size thresholds. The overall management basis for the complex is thus less affected by species near those thresholds. If it is not possible to change the selectivity for the weakest species in the complex, then change affecting all species must be implemented.

The status of the "weakest" species determines the imposition of management actions. The law does not discriminate among commercially important species and other species. If biomass or fishing mortality rates for any species fall outside the individual harvest control rule for that species, then management action is implemented which could affect fishing activity for other species in the complex.

Biological reference points (or proxies) and harvest control rules for each stock in the mixed-stock complex should be developed, even though information may be limited. In order to prevent irreversible changes in species composition or diversity, the fishing mortality rate should not exceed the limit for any individual stock in a mixed-stock complex; the precautionary target control rule for that individual stock should apply. Similarly, if values of indices fell below precautionary target biomass levels (or their proxies or other buffer-type values above the limit, where estimates of fishing mortality rates were unavailable), then the precautionary target control rule would apply. The relevant control rule should be implemented regardless of the level of information from which the rule was developed. This should lessen the possibility of reducing less-productive stocks to levels at which they would require protection under the ESA, especially if relatively little were known about those stocks.